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JP Kokai Hei 5-101871

[Title of the Invention] CERAMIC HEATER

[Abstract]

[Object]

To provide a ceramic heater excellent in durability and reliability in a joining part of a resistance heating element and an electric power supply cable and capable of preventing interior contamination and heat efficiency deterioration in a device such as a semiconductor producing device in which a high temperature and corrosive gas is to be used.

[Configuration]

A resistance heating element 8 made of a high melting point metal such as tungsten or the like is embedded in the inside of a dense ceramic substrate 7. A crimp part 1b of a bulk terminal 1 is electrically connected to an end part 8a of the resistance heating element 8. The surface 5 of the bulk terminal 1 embedded in a ceramic substrate is exposed in the heater rear face 9 side. The thermal expansion coefficient of the high melting point metal composing the bulk terminal 1 is equal to or higher than that of the ceramic substrate 7. The bulk terminal 1 is joined to a terminal 6 at the end of the electric power supply cable by, for example, screwing.

[Claims]

1. A ceramic heater comprising:

a dense ceramic substrate;

a resistance heating element embedded in the inside of the ceramic substrate and made of a high melting point metal; and

a bulk terminal electrically connected to the resistance heating element and embedded in the ceramic substrate while the surface being exposed, wherein

said bulk terminal is made of a high melting point metal having a thermal expansion coefficient equal to or more than that of said ceramic substrate.

2. The ceramic heater according to claim 1, wherein

said resistance heating element is made of a high melting point metal having a thermal expansion coefficient smaller than that of said ceramic substrate.

3. The ceramic heater according to claim 2, wherein

said ceramic substrate is made of aluminum nitride and said

resistance heating element is substantially made of tungsten.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a ceramic heater advantageously usable for a device for plasma CVD, a vacuum CVD, a plasma etching, optical etching or the like.

[0002]

[Prior Art]

In a semiconductor producing device requiring super clean state, a corrosive gas such as chloride type gas, fluoride type gas and the like is used as a gas for deposition, a gas for etching, a gas for cleaning and the like. For that, if a conventional heater comprising a resistance heating element coated with a metal such as a stainless steel, Inconel and the like in the surface is used as a heating device for heating a wafer in the state that the wafer is brought into contact with such a corrosive gas, undesirable particles of chlorides, oxides, fluorides and the like with a particle diameter of several μm are formed owing to exposure to the gas.

[0003]

Therefore, an indirect heating type wafer heating device has been developed in which an IR lamp is installed in the outside of a container to be exposed to a gas for deposition, an IR transmissive window is installed in the outer wall of the container, infrared rays are radiated to an object to be heated made of a material with a high heat resistance such as graphite, and a wafer put on the upper face of the object to be heated. However, as compared with a direct heating type one, this type device has problems that the heat loss is high, the temperature increase takes time, transmittance of infrared rays is gradually deteriorated owing to deposition of a CVD film on the IR transmissive window, and that the window is heated owing to heat absorption in the IR transmissive window.

[0004]

[Problems to be Solved by the Invention]

In order to solve the above-mentioned problems, the present inventors have made investigation on a heating device comprising a ceramic heater having a resistance heating element embedded in a disk-like dense ceramic and held in a case made of graphite. As a result, the heating

device has been found to be an excellent device sweepingly solving the above-mentioned problems.

[0005]

However, in order to use such a ceramic heater practically for a semiconductor device, problems are found still remaining. For example, regarding a heater for a glow plug made of silicon nitride disclosed in Japanese Utility Model Publication No. 60-30611, electrode parts are disposed in atmospheric air at 500°C or less and linear resistance heating element terminals and electrode cables are soldered by a silver solder to form electric communication. That is, even if the heating part is at a high temperature, the electrode parts of the heater can be formed in the outside of the casing where the temperature is low.

[0006]

Whereas, in the above-mentioned ceramic heater, since the resistance heating element is formed by press forming while being set in a ceramic powder, the ceramic heater is required to have a simple shape and even in the firing step, that is the same since hot press firing is carried out. Moreover, there is a firing modified layer, so-called black coating, on the surface of the fired body after firing and therefore, the modified layer is required to be removed by machining. At that time, grinding by a diamond wheel is needed to result in cost up if the shape is complicated. As described, in the case of a ceramic heater comprising a resistance heating element embedded therein, from a viewpoint of manufacturing difficulty, the shape is required to be simple just like a disk-like shape. Because of such reasons, terminal parts of the resistance heating element cannot be led out a casing and connection parts of the resistance heating element and electric cables are repeatedly exposed to a high temperature and corrosive gas.

[0007]

An object of the present invention is to provide a ceramic heater excellent in durability and reliability in a joining part of a resistance heating element and an electric power supply cable and capable of preventing interior contamination and heat efficiency deterioration in a device such as a semiconductor producing device in which a high temperature and corrosive gas is to be used.

[0008]

[Means for Solving the Problems]

The present invention relates to a ceramic heater comprising: a dense ceramic substrate; a resistance heating element embedded in the inside of the ceramic substrate and made of a high melting point metal; and a bulk terminal electrically connected to the resistance heating element and embedded in the ceramic substrate while the surface being exposed, wherein the bulk terminal is made of a high melting point metal having a thermal expansion coefficient equal to or higher than that of the ceramic substrate.

[0009]

[Examples]

At first, an overall constitutional example of a ceramic heater will be described. Fig. 6 is a cross-sectional view showing a ceramic heater attached to a thermal CVD device. Reference numeral 40 denotes a container to be used for semiconductor producing CVD and 10 denotes a disk-like ceramic heater attached to a case 50 in the inside for heating wafer and the wafer heating face 16 is made sufficiently wide to install a wafer of 4 to 8 inch thereon.

[0010]

Gases for thermal CVD are supplied from gas supply holes 27 to the inside of the container 40 and the interior air is discharged out through a suction hole 28 by a vacuum pump. The disk-like ceramic heater 10 comprises a dense and gas-tight disk-like ceramic substrate 7 and a resistance heating element 8 embedded in the shape of spiral in the inside of the substrate.

[0011]

Reference numeral 20 denotes a flange equipped with a water-cooling jacket covering the upper face of the case 50 and the gap to the side wall of the container 40 is sealed with an O ring 26 to form the ceiling face of the container 40. Reference numeral 18 is a hollow sheath inserted into the inside of the container 40 while penetrating the wall face of the flange 20 of the container 40 with such a structure and joined to the ceramic heater. A thermocouple 17 equipped with a stainless sheath is inserted into the hollow sheath 18. An O ring is installed between the hollow sheath 18 and the flange 20 of the container 40 to prevent atmospheric air penetration.

[0012]

A bulk terminal 1, which will be described later, is joined to a

terminal of the resistance heating element 8. A terminal 6 is formed in the terminal of an electric power supply cable 11 and the terminal 6 and the bulk terminal 1 are joined in a manner to be described later. Through the electric power supply cable 11, electric power is supplied from the outside to enable the disk-like ceramic heater to heat to, for example, at the highest 1100°C.

[0013]

Next, the constitution of the bulk terminal 1 will be described with reference to Figs. 1 to 5. In this example, the bulk terminal 1 and the resistance heating element 8 are joined to each other by so-called cramping. That is, at first, the bulk terminal 1 as shown in Figs. 3 and 4 is provided. The bulk terminal is made of a high melting point metal and composed of a column-like main body 1a and cylindrical cramping part 1b.

[0014]

An end part 8a of the resistance heating element 8 is inserted into the space 2 of the cramping part 1b and as shown as an arrow B in Fig. 3, pressure is applied to the cylindrical cramping part 1b to deform the cramping part 1b as shown by a one point-dotted line to fix the heating element end part 8a. In the cramping step, the bulk terminal 1 is preferable to be heated in gas reducing environments at a temperature as high as 800°C or more.

[0015]

Next, the bulk terminal 1 is embedded in a ceramic formed body and the ceramic formed body is fired to produce a ceramic substrate 7 and the rear face 9 side of the ceramic substrate 7 is ground to expose the end face 5 of the bulk terminal 1 as shown in Fig. 5. A female screw 3 is to set in bulk terminal and in some cases, the female screw 3 may be set before the embedding in ceramic formed body.

[0016]

In such a state, the cramping part 1b is pressed as shown in Fig. 1, when observed in a cross-sectional view taken along line I-I in Fig. 3 and the cramping part 1b is expanded as shown in Fig. 2, when observed in a cross-sectional view taken along line II-II. The resistance heating element end part 8a and the cramping part 1b are joined to each other by so-called cramping structure. A male screw 6a of the terminal 6 is screwed in the female screw 3.

[0017]

Further, according to the present invention, the bulk terminal 1 is made of high melting point metal having a thermal expansion coefficient higher than that of the ceramic substrate 7. The material of the ceramic substrate 7 is preferably ceramics such as aluminum nitride, sialon, silicon nitride and the like. Especially, according to the investigations by the present inventors, in the case of a ceramic heater for semiconductor producing device, aluminum nitride has been found preferable for the substrate. That is, because aluminum nitride has been found having considerably high corrosion resistance to halide type corrosive gases such as ClF_3 to be used for the semiconductor producing device.

[0018]

Hereinafter, thermal expansion coefficients of preferable dense ceramics and high melting point metals to be used for the bulk terminal 1 and the resistance heating element 8 will be shown:

tungsten	4.35×10^{-6}/°C,
molybdenum	5.20×10^{-6}/°C,
niobium	7.31×10^{-6}/°C,
tantalum	6.5×10^{-6}/°C,
rhenium	6.70×10^{-6}/°C,
rhodium	8.30×10^{-6}/°C,
iridium	6.8×10^{-6}/°C,
osmium	4.6×10^{-6}/°C,
aluminum nitride	4.50×10^{-6}/°C,
sialon	3.20×10^{-6}/°C, and
silicon nitride	3.0×10^{-6}/°C.

[0019]

With the ceramic heater of this example, problems such as contamination in the case of using a conventional metal heater and deterioration of heat efficiency in the case of employing an indirect heating method can be solved.

[0020]

Then, since a variety of corrosive gases are used in a semiconductor producing device, the corrosive gases inevitably penetrate in the heater rear face 9 side. For that, the joining parts of the bulk terminal 1 and the terminal 6 are repeatedly heated to a high temperature and cooled. In

such severe conditions, the joining parts are rapidly deteriorated if joining is carried out by conventional soldering. However, at that point, the bulk terminal 1 and the terminal 6 are joined through screws, so that deterioration of the joining parts owing to the corrosive gases and heating can be prevented to result in improvement of durability and reliability of the heater.

[0021]

Moreover, in this case, it is important to use a bulk terminal but not a linear terminal just like the case of, for example, a conventional heater for a glow plug and owing to that, the shape of the exposed face 5 is made circular and the surface area is widened and thus the female screw is made possible to be installed. For example, in the case of employing a threading method just like this example, the exposed face 5 is made to have a diameter of, for example, 5 mm, a length of the main body 1a of 8 mm. Further, the cramping part 1b is made to be a thin cylindrical shape with, for example, an outer diameter of 3 mm, an inner diameter of 2 mm, and a length of 3 mm and, for example, a resistance wire made of tungsten and having a diameter of 0.4 mm is joined thereto. By using such a bulk terminal, heat resistant and corrosion resistant electrode joining is made possible.

[0022]

Further, it is also important the bulk terminal 1 is made of a high melting point metal having a thermal expansion coefficient higher than that of the ceramic substrate 7. The reasons for that will be described below.

[0023]

The present inventors practically produced such a ceramic heater 10 shown in Figs. 1 to 6. Incidentally, the ceramic substrate 7 is made of aluminum nitride and a wire made of tungsten with a diameter of 0.4 mm which was wound just like a coil was used as the resistance heating element 8. The main body portion of the bulk terminal 1 was made of tungsten and the outer shape was made to be a column-like shape with a diameter of 5 mm and a length of 8 mm. However, in the case the bulk terminal 1 was embedded at a prescribed position of a formed body for the ceramic substrate and the formed body was fired, cracking was found occurring in the surrounding of the bulk terminal 1 at the time of cooling after firing.

[0024]

Especially, as shown in Fig. 7, the cross-sectional view of the bulk

terminal 1 in the vertical direction made it clear that cracks 21 were formed in the portions where the outline of the outer shape of the bulk terminal 1 is bent. Also, as shown in Fig. 8, the plan view from the heater rear face 9 side, the cracks 21 were found extended radially to the outside from the outer circumference of the bulk terminal 1 with a truly circular shape in the plan view. However, in the surrounding of the resistance heating element 8, no such crack was formed.

[0025]

Therefore, the present inventors have investigated further in details and found that no crack is formed in the ceramic substrate 7 if the thermal expansion coefficient of a high melting point metal composing the bulk terminal is higher than the thermal expansion coefficient of aluminum nitride. That is supposedly attributed to the relation between the thermal shrinkage degree of the ceramic substrate 7 and the thermal shrinkage degree of the bulk terminal 1 after firing.

[0026]

The reasons for no crack formation in the surrounding of the resistance heating element have been also investigated. Consequently, even in the case the thermal expansion coefficient of the high melting point metal composing the bulk terminal is smaller than that of aluminum nitride, if the diameter of the column-like embedded material is 2.0 mm or less, it is found that no cracking occurs. In the above-mentioned example, the diameter of the resistance heating element 8 is 0.4 mm, preferably 0.8 mm or less. Like that, that the size of the embedded material affects occurrence of cracking is an unexpected matter and the reason for that is not clear.

[0027]

Occurrence of cracking was investigated by embedding a variety of materials in various sizes in aluminum nitride and the results of the experiments will be described. The following respective materials to be embedded having the shapes and sizes as described below were embedded in an aluminum nitride formed body containing 5% by weight of Y_2O_3, fired at 1900°C for 2 hours, cooled, and subjected to investigations on crack formation.

[0028]

No.	material	shape	size (mm)

1	W	coil-like wire	diameter 0.4
2	W	coil-like wire	diameter 1.0
3	W	bulk terminal 1	diameter 3.0, length 5
4	W	bulk terminal 1	diameter 5.0, length 8
5	Mo	bulk terminal 1	diameter 5.0, length 8
6	Nb	bulk terminal 1	diameter 5.0, length 8
7	Ta	bulk terminal 1	diameter 5.0, length 8
8	Re	bulk terminal 1	diameter 5.0, length 8
9	Rh	bulk terminal 1	diameter 5.0, length 8
10	Ir	bulk terminal 1	diameter 5.0, length 8
11	Os	bulk terminal 1	diameter 5.0, length 8

Incidentally, regarding the samples of Nos. 3 to 11, the values shown in the size column are those of the column-like main bodies 1a of the bulk terminals 1.

[0029]

In the above descriptions, regarding the samples of Nos. 1, 2, 5, 7, 8, 10 and 11, no crack was formed and no adhesion failure between the embedded materials and aluminum nitride took place. In the sample of No. 3, fine cracks were formed in the substrate. That was attributed to the effect of the thermal expansion coefficient of tungsten slightly smaller than that of the ceramic substrate. In the sample of No. 4, cracking occurs. In the sample of No. 6, niobium was used and in the sample of No. 9, rhodium was used, in both cases, obvious adhesion failure between the column-like main bodies and the ceramic substrate was caused.

[0030]

Also, in the above-mentioned sample of No. 5, according to observation by a microscope, a slight gap between the column-like main body made of molybdenum and aluminum nitride was confirmed. Therefore, an alloy containing 20% of molybdenum and 80% of tungsten was provided and a main body with a length of 8 mm and a diameter of 5.0 mm was provided. The thermal expansion coefficient of the alloy was $4.95 \times 10^{-4}/°C$. In this case, no gap between the column-like main body and aluminum nitride was observed in a microscopic photograph.

[0031]

Further, regarding the above-mentioned samples of Nos. 6 and 9, disconnection took place between the bulk terminals 1 and the coil-like

wires (that is, resistance heating elements 8) connected thereto. On the other hand, in the case a column-like body was made of an alloy containing 20% of molybdenum and 80% of tungsten, defective electric connection, disconnection and the like were not caused at all even if a cycle; heating from a room temperature, keeping at 1000°C for 1 hour, and cooling to a room temperature; was repeated 1000 times.

[0032]

As the material for the resistance heating element 8, the respective high melting point metal as shown in the above-mentioned table may be used. Incidentally, as described already, if the diameter of the resistance heating element 8 was 2.0 mm or less, even if the resistance heating element 8 was made of tungsten, no crack was formed in the ceramic substrate 7. Accordingly, if the size is within the above-mentioned range, it is preferable to produce the resistance heating element 8 from tungsten. If the resistance heating element 8 is made of, for example, molybdenum, when it is heated to a high temperature, metal particle growth takes place in the inside of the resistance heating element 8 and consequently, the resistance heating element 8 becomes fragile to probably result in disconnection.

[0033]

Next, in the example shown in Figs. 1 to 6, the effects attributed to the specific shape of the bulk terminal 1 will be described. As described above, the bulk terminal 1 has a thermal expansion coefficient higher than the ceramic substrate 7. Accordingly, during the cooling after firing the ceramic substrate 7, the shrinkage degree of the bulk terminal 1 is higher than the shrinkage degree of the ceramic substrate 7. Due to that, a slight gap between the main body 1a and the ceramic substrate 7 may be formed in some cases. As described above, there scarcely occurs a problem if the bulk terminal 1 is made of a Mo-W alloy, however in the case the gap between the main body 1a and the ceramic substrate 7 is wide, if there is no cramping part 1b, the bulk terminal could be dropped. At that point, in this example, since the main body 1a is engaged in the ceramic substrate 7 by the cramping part 1b, there is no probability for the bulk terminal 1 to drop off.

[0034]

Further, if there is no cramping part 1b, in the case the difference of

the thermal expansion coefficient between the ceramic substrate 7 and the main body 1a is significant, as described above, a gap is formed between them and the bulk terminal would be swung. Owing to the swinging, the fragile resistance heating element 8 is pulled and disconnection of the resistance heating element 8 probably occurs. Further, a corrosive gas in a CVD device enter through the gap between the main body 1a and the ceramic substrate 7 to probably cause direct corrosion of the resistance heating element 8. In such a case, the conductivity of the bulk terminal and the resistance heating element 8 is deteriorated.

[0035]

At that point, as shown in Fig. 2, it is important to form the cramping face 12 between the bulk terminal 1 and the ceramic substrate 7 in a region between the cramping part 1b and the main body 1a by fitting by firing, which will be described later. That is, in the step of embedding the bulk terminal 1 in the ceramic formed body, the formed material enters in a gap between the main body 1a and the cramping part 1b. After that, when the resulting formed body is fired, in the cooling step after the firing, since the thermal shrinkage of the bulk terminal 1 made of the heat resistant metal is more than the thermal shrinkage of the ceramic substrate 7, the compressive stress as shown by the arrow A affects to form the cramping face 12. The present inventors call such fixation method as fitting by firing. Formation of the cramping face 12 by fitting by firing makes it possible to prevent the bulk terminal 1 from swinging.

[0036]

Further, since the ceramic forming material enters in the space 2 in the cramping part 1b, the cramping face is formed similarly by fitting by firing as described above and owing to the cramping face, the gap to the ceramic substrate 7 can be air-tightly sealed. Consequently, the contact part 33 between the bulk terminal 1 and the resistance heating element 8 is prevented from exposure to a corrosive gas, so that electric conduction deterioration and failure in the contact part 33 can be prevented.

[0037]

Further, since the thermal shrinkage degree of the bulk terminal 1 is higher than that of the ceramic substrate 7, the cramping face by the fitting by firing is always formed in the heating cycle in the case of using as a heater at the firing temperature or less and therefore they are stable in

the cooling and heating cycles. To fire the above-mentioned ceramic formed body, normal pressure firing is possible, however a hot press method and a hot isostatic press method are preferable since they are capable of eliminating the gap between the bulk terminal and the formed material. Further, at the time of producing the disk-like ceramic substrate 7 as shown in Figs. 1 to 6 by hot press firing, it is preferable to adjust the length of the bulk terminal to be t/2 or less and the diameter of the exposed face 5 to be t/4 or less wherein the reference character t denotes the thickness of the substrate 7. Further, the diameter of the exposed face 5 is preferably 4 mm or more since mechanical bonding by such as threading and various heat resistant and corrosion resistant bonding by diffusion joining, which will be described later, are to be formed.

[0038]

In the example shown in Fig. 1, the bonding of the bulk terminal 1 and the terminal 6 was carried out by threading method, however bonding methods are not limited to that other joining and bonding methods stable to cooling and heating cycles between a room temperature and the heater use temperature can be employed. The following joining and bonding methods are available.

[0039]

The following are the methods for joining through a high melting point joining layer:

(1) diffusion joining between a bulk terminal and a terminal in the electrode cable side through a powder of a high melting point metal such as Mo, W and the like;

(2) joining with a solder material;

(3) diffusion joining through a foil;

(4) forming a coating layer on an end face of a bulk terminal or an end face of a terminal in the electrode cable side by plating, CVD, spraying or the like and then diffusion joining or friction pressure joining them; and

(5) welding.

As a mechanical bonding method, mechanical press bonding methods by a pressure insertion method, caulking, embedding, interposing, using a spring, and using an elastic board are available.

[0040]

The shape of the main body 1a of the bulk terminal 1 can be changed

variously and for example, it may be a trigonal pillar, an elliptical pillar, a tetragonal pillar, a hexagonal pillar and the like. The method for joining the resistance heating element to the bulk terminal, other than the above-mentioned method by caulking, methods by winding, welding and the like can be possible.

[0041]

The shape of the ceramic heater of above-mentioned each example, it is preferable to be disk-like in order to evenly heat a circular wafer, however the shape may be other shapes such as a tetragonal board-like shape, a hexagonal board-like shape and the like. In the above-mentioned example, aluminum nitride containing Y_2O_3 as an additive was used. By changing the additive, the thermal expansion coefficient of aluminum nitride and the thermal expansion coefficient of the bulk terminal can be adjusted to satisfy the relation defined in the present invention.

[0042]

[Effects of the Invention]

As described above, according to the present invention, since a resistance heating element made of a high melting point metal is embedded in the inside of a dense ceramic substrate, problems such as contamination in the case of using a conventional metal heater and deterioration of heat efficiency in the case of employing an indirect heating method can be solved.

[0043]

Further, since the surface of the bulk terminal electrically connected to the resistance heating element is exposed, firm and heat resistant and corrosion resistant bonding of the surface of the bulk terminal and a terminal in the electric power supply side can be formed. Accordingly, deterioration of the bonding parts attributed to a corrosive gas and heat can be prevented to improve the durability and the reliability of a heater.

[0044]

Moreover, since the bulk terminal is made of a high melting point metal having a higher thermal expansion coefficient than the thermal expansion coefficient of the ceramic substrate, in the cooling step after firing, the shrinkage degree of the bulk terminal is higher than the shrinkage degree of the ceramic substrate. Consequently, no forcible stress is caused in the surrounding of the bulk terminal and therefore, no crack is formed in the ceramic substrate.

[Brief Descriptions of the Drawings]
[Fig. 1]
Fig. 1 is a cross-sectional view showing the state that a bulk terminal 1 is embedded in a ceramic substrate 7, and corresponds to the cross-sectional arrow view taken along line I-I in Fig. 3.
[Fig. 2]
Fig. 2 is a cross-sectional view showing the state that a bulk terminal 1 is embedded in a ceramic substrate 7, and corresponds to the cross-sectional arrow view taken along line II-II in Fig. 3.
[Fig. 3]
Fig. 3 is a bottom view showing the state of a bulk terminal 1 before caulking cramping.
[Fig. 4]
Fig. 4 is a cross-sectional view showing the state of a bulk terminal 1 before caulking cramping.
[Fig. 5]
Fig. 5 is a ruptured perspective view showing the state of a bulk terminal 1 embedded in a ceramic substrate 7.
[Fig. 6]
Fig. 6 is a cross-sectional view schematically showing the state of a ceramic heater 10 attached to a container of a thermal CVD device.
[Fig. 7]
Fig. 7 is a cross-sectional view showing the state that cracks 21 are formed in a ceramic substrate 7 embedding a bulk terminal 1 therein.
[Fig. 8]
Fig. 8 is a plan view showing the state that cracks 21 are formed in the rear face 9 side of a ceramic substrate embedding a bulk terminal 1 therein.
[Descriptions of the Reference Numerals]
1 bulk terminal
5 surface of bulk terminal 1
6 terminal in electric power supply cable side
7 ceramic substrate
8 resistance heating element
9 heater rear face
10 disk-like ceramic heater

11 electric power supply cable
12 cramping face
21 crack
40 container